PORTO RICO AGRICULTURAL EXPERIMENT STATION.

D. W. MAY, Special Agent in Charge.

Mayaguez, P. R. April, 1910.

Bulletin No. 9.

SUGAR CANE IN PORTO RICO.

BY

D. W. MAY.

SPECIAL AGENT IN CHARGE.

UNDER THE SUPERVISION OF

OFFICE OF EXPERIMENT STATIONS,

U. S. Department of Agriculture.

MAYAGUEZ, P. R.
"BANDERA AMERICANA" JOB PRINTER.
1910.

FIG. 1.—SEEDLING CANES IN POTS.

FIG 2.—SEEDLING CANES IN THE FIELD.

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PORTO RICO AGRICULTURAL EXPERIMENT STATION.

(Under the supervision of A. C. TRUE, Director of the Office of Experiment Stations, United States Department of Agriculture.)

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LETTER OF TRANSMITTAL

Porto Rico Agricultural Experiment Station,

Mayaguez, P. R. April 4, 1910.

Sir: I have the honor to transmit herewith a manuscript on the subject of Sugar Cane in Porto Rico.

The data presented cover several phases of the production of this the leading crop of the Island now resulting in a value of eighteen million dollars annually.

I respectfully recommend that this manuscript be issued as Bulletin No. 9 of this station, and that it be published in both English and Spanish.

Respectfully,

D. W. MAY,

Special Agent in Charge.

Dr. A. C. TRUE,

Director Office of Experiment Stations,

U. S. Department of Agriculture, Washington, D. C.

Recommended for publication

A. C. TRUE, *Director.*

Publication authorized.

JAMES WILSON,

Secretary of Agr culture.

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INTRODUCTION.

Sugar, one of the principal commercial products of the world, is obtained practically from two sources, the sugar cane and the sugar beet. For a long time it was largely obtained from the sugar cane, but later, because of certain economic and political reasons, the sugar beet became quite a factor in the production of sugar, in time even surpassing in amount the production of the sugar cane. While sugar can be produced more economically from the sugar cane, yet the sugar beet has for various causes held the position for a number of years of exceeding it in total yield of sugar. This has been for two reasons, first, because of certain tariffs and bounties favoring it and, second, because of the scientific breeding and care employed in cultivating and manufacturing beet root sugar.

Sugar produced from cane has been so long used that its beginning is not clearly known. It was doubtless obtained very early in the history of mankind and its use widely diffused. Even to-day a great deal of cane sugar is produced in obscure quarters of the globe by very primitive means and is consumed locally, the statistics not reaching the chronicles of trade.

The sugar cane belongs to the grass family and is only one of the many varieties of grasses that enter into the welfare of the human race. "All flesh is grass," said the prophet, and truly when we consider the intimate role this family of plants plays in providing sustenance to animal life. Of the many grasses, as malojilla, guinea, maize, and cane, that enter so largely into the prosperity of Porto Rico, the latter is by far the most important, making up more than two-thirds of the total exports, reaching an aggregate of eighteen millions of dollars annually. A study, therefore, of the plant together with its best and most economical production may not be amiss at this time, for any betterment in this crop touches the very foundation of the prosperity of Porto Rico. In such a treatise

the object is not only to show the findings in the experiments made with cane in Porto Rico, but to combine and draw lessons from the results obtained in other cane-growing countries.

The sugar cane does not differ essentially from other well-known grasses. By keeping this fact in mind we can better understand by methods of comparison many facts connected with its growth. The essential part of the sugar cane is the stalk that is developed with the growth of the plant. This consists in the mature cane of the stem from the surface of the ground to the bunch of leaves forming the head. It is made up of joints of varying widths composed of a hard shell inclosing a pith carrying the sweet juice. Considering the size of the cane plant the root system is not extensive. This varies, however, with the physical and chemical character of the soil. In a hard compact soil the roots do not travel far. In an open porous soil the main portion of the root system is in a rather prescribed area, but small roots and their filaments reach out some distance. The extent of the root system is also affected by the fertility and the moisture content of the soil. In a poor soil the roots go farther in search of plant food. This is also the case when moisture is lacking. In time of drought the cane sends its roots very far in search of water; then when the season becomes more favorable the plant very quickly recovers, its extensive root system giving it a wide feeding surface. Recovery from drought is therefore often noticed as being very rapid. In very rich soil the plant is often so abundant that the roots do no extend far enough to support its growth and in that case it sometimes topples over, especially when frequent rains soften the surrounding soil.

Sugar cane has from the beginning been propagated by cuttings. There exists the tendency under such methods of the plant running out. When the cane is propagated by seeds, which is the natural way, we should expect a great improvement. Harrison and Bovell began a number of years ago in Barbados (a) to grow new varieties of cane from the minute seed found in the arrows. This work has been extended and very valuable results have been attained. Already the seedling canes are rapidly supplanting the old varieties in the West Indies and it will be only a matter of a few years until the latter are entirely gone. While most of the seedlings are inferior to the kinds usually grown yet we can expect to get a few of exceptional merit out of every thousand grown. Great improvement has been brought about in this way with other plants produced from cuttings, notably the potato. We may expect equally favorable results with cane. While the phenomenal cane has not yet been obtained by growing new varieties of cane from seed, yet we may surely expect it from the results already attained.

(a) Roy. Bot. Gard. Kew, Bul, Misc. Inform., 1888, No. 24, p. 294; Imp. Dept. Agr. West Indies, Rpt. Agr. and Bot. Depts. Barbados, 1898–1907, with Review of Sugar-Cane Expts. since 1884.

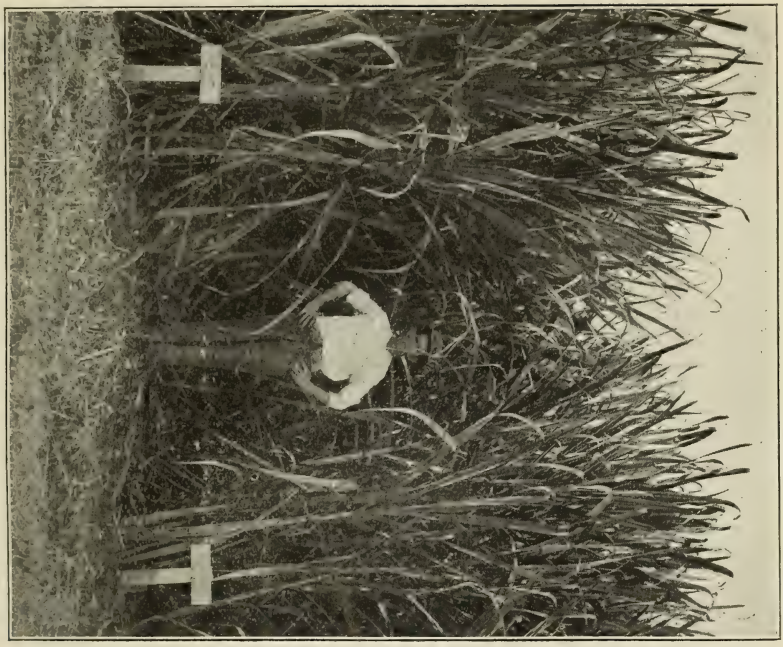

FIG. 1.—FERTILIZER EXPERIMENTS WITH CANE.
LIME AND MANURE.

FIG. 2.—ROOT SYSTEM OF SUGAR CANE.

VARIETIES OF CANE.

Cane, like other plants propagated from cuttings, varies much in different soils and climates. Tracing the origin and history therefore of any particular variety is very difficult. A variety taken from one island of the West Indies to another sometimes loses its identity and becomes known after a time under an entirely new name.

The three most common varieties now grown in Porto Rico are the Cristalina, the Otaheite or White, and the Rayada or Striped. One variety will prove best in one locality and prevail, while in other sections another will do best. Again it is often found advisable to change the variety on a certain piece of land. It appears that not only does the rotation of the crop prove advisable but that often a change in the variety will prove of advantage.

Two lesser known varieties in Porto Rico are the Penang and Convangerie or French cane. The former grows well on very heavy wet lands and the latter is very free from disease. The French cane is said to have been introduced from Mauritius during a time in the seventies when disease was rampant. Neither of these two canes is in the first class as a sugar producer.

The experiment station and the Guanica Centrale are growing new varieties of cane from seed. Several thousand of these have already been produced, but not sufficient time has elapsed to thoroughly test them as sugar producers. In the meantime a number of seedling canes produced and tested by the British stations have been under trial. A few comments on them will doubtless prove interesting. These canes are numbered, those with the letter B preceding were produced in Barbados, those with the letter D in Demerara, and those with T in Trinidad. A great many cuttings from these canes have been sent to planters in different sections of Porto Rico and have been very favorably received. In general they have proven superior to the old varieties not only in showing increased sugar production but in hardiness and freedom from disease. The laboratory tests while of course inconclusive have shown a fair average increase in sucrose over the old varieties. Some mill tests made by the Guanica Centrale also show up very favorably for the seedling canes.

At the experiment station the following varieties have given excellent results: D95, D117, B347, and B1355. As resistant to drought T77, D117, B347, and B3289 have done well on the south side of the island. At the Central San Gristobal on the east end of the island the preliminary test of seedling canes has been very satisfactory, and so far as tested, they are ranked as follows: T77, B3289, B347, D117, and D95. In Louisiana, D74 is highly considered. In Porto Rico, however, while very sweet this cane does not grow large, as it ripens early. It is well suited to a short growing season like that in Louisiana. The Guanica Centrale on the south side of Porto Rico has several hundred acres of seedling canes growing. The following results obtained there are of interest and value.

In this district, canes were planted October 1, 1907, 5½ by 5½ feet, and harvested December 22 and 23, 1908. All varieties were fertilized, irrigated, and cultivated alike.

Comparative test of cane at Guanica Centrale.

VARIETY	YIELD PER ACRE	Density	Sucrose	Quotient of purity	Glucose	Glucose ratio	FIBER
	Tons.	°Brix	Percent		Percent		Percent
Otaheite (a)	56.38	15.7	12.7	80.9	2.00	15.8	9.50
T77	65.42	18.2	15.1	83.0	1.61	10.7	9.95
D117	56.45	18.5	15.4	83.2	1.69	11.0	11.8
D95	52.77	18.1	15.8	87.3	1.51	9.6	10.05
B1753	52.99	16.3	12.8	78.5	1.89	14.8	12.10
Cristalina (b)	52.08	16.9	13.4	79.3	1.79	13.4	9.65
D74	49.01	19.9	17.6	88.4	1.43	8.1	10.85
W. Bamboo	47.52	16.9	13.2	78.1	2.17	16.4	10.70
Tibboo Merd	43.46	16.3	13.6	83.3	1.79	13.2	10.30

(a) Control Plot. Attacked by fungus disease (Marasmius sacchari).
(b) Slightly attacked by fungus disease (Marasmius sacchari).

At Hacienda Monserrate the following varieties of canes were planted September 25, 1907, and harvested December 29, 1908. All varieties were fertilized and cultivated alike.

Comparative test of varieties of cane at Hacienda Monserrate.

VARIETY	YIELD PER ACRE	Density	Sucrose	Quotient of purity	Glucose	Glucose ratio	FIBER
	Tons.	°Brix	Percent		Percent		Percemt
W. Bambo	64.66	16.9	13.	76.9	1.85	14.2	10.6
D117	64.60	17.5	15.	85.7	1.79	11.9	11.
B347	60.24	17.8	15.3	85.9	1.96	12.8	9.45
Tibboo Merd	52.51	16.1	14.2	88.2	1.72	12.1	11.3

In Louisiana splendid results have been obtained by the introduction of D74 and D95, two Demerara seedlings. Louisiana Station Bulletin 78 gives the history of these seedling canes, and the results of tests conducted from 1894 to 1903 are reported. In every instance the two seedlings were lower in glucose con'ent than the home canes. A low glucose content is of great advantage in working the juice. D74 gave especially favorable results in this respect. The average analysis showed that this seedling contained

1.8 per cent more sucrose and D95 0.9 per cent more than the home canes. D74 yielded 5.68 tons of cane more per acre than the two native varieties, while D95 was about equal to them in cane production. The financial results are based on a value of 4 cents per pound for yellow clarified sugar, giving half to the producer of the cane and half to the manufacturer of the sugar. On this basis the crop of plant-canes and first year's ratoons of D74 gave an average increase of $39.70 per acre and D95 of $21.81 over the home canes. With the plant-canes of the first, second, and third ratoons the figures were $26.28 and $28.14 per acre, respectively. The results obtained in the mill showed a marked superiority of D74 over the three other canes, although D95 gave better returns than the two native sorts. In total extraction D74 showed an increase of 7.87 per cent, or nearly 11 per cent in the juice over the home canes. A summary of the results gives an increase of 2.34 per cent in extraction, and of 40.7 pounds of sugar per ton of cane ground in favor of the seedling canes. Cooperative tests made by 27 planters throughout the State confirmed the results obtained by the station. D74 is more vigorous, a more rapid grower, gives a larger tonnage, is an erect cane, and on this account is believed to be more economical in harvesting, stubbles well if not better than home cane, gives a larger extraction, and has a larger sugar content, yielding more sugar per ton and giving a greater tonnage per acre than home canes. The same remarks in a lesser degree apply to D95.

At the Hawaiian Sugar Planters' Station in 1906 (a) 5,232 seedling canes were grown. Of 279 raised from West Indian seed imported in 1904, 37 have been sufficiently promising to merit special testing on the station grounds. Test of varieties in 1903 (b) shows D117 at head of list with 333,670 lbs. cane, yielding 43,010 lbs. sugar per acre.

J. P. D'Albuquerque and J. R. Bovell report in Barbados in 1906 (c) that D95 gave 9,216 pounds of sugar per acre as compared with 6,876 pounds for White Transparent, the variety formerly grown. This difference in Barbados represents a value of $24.34 per acre. Sugar in the English colonies is much lower than in Porto Rico. Such a difference here would be much greater. As plant-canes and ratoons on red soils in Barbados, B1566 gave a yield representing a gain of $47.30 over White Transparent.

In the Jamaica report for 1905 (d) the seedling cane B208 gave the best results.

J. B. Harrison in the Demerara report for 1905 (e) says that on one estate seedling varieties of cane gave a yield of 7 per cent and on another

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(a) Hawaiian Sugar Planters' Sta. Rpt. 1906, p. 27.
(b) Hawaiian Sugar Planters' Sta. Rpt. 1903, p. 24.
(c) Rpt. Agr. Work Barbados, Imp. Dept. Agr. West Indies, 1904–1906, pt. 3, p. 2.
(d) Rpt. Jamaica Sugar Exp. Sta. 1905, p. 59.
(e) Report on Results of Experiments with Varieties of Canes. Georgetown, Demerara: Bd. Agr. 1905, p. 6

30.7 per cent greater than Bourbon, the variety usually grown.

At the Java Experiment Station in 1907 (a) as a result of breeding seedling canes by means of crossing and chemical selection, it was found that canes highest in sugar grown from canes that were high in sugar were heavier than canes grown from others low in sugar. It was also found that more seedlings were obtained from plants high in sugar than from those low in sugar. The chances of obtaining seedlings high in sugar were three times as great when using parents of a high content than when using parents of a low content.

In securing new varieties of cane the objects in view are to secure varieties that will give a greater tonnage per acre and thereby an increase in yield of sugar; the breeding of varieties that will give a higher percentage of sucrose in the juice with a decrease in the impurities; and to secure canes that are hardy and less liable to the attacks of fungus diseases and insects. The following are the good points of cane: Early growth; hardiness and ability to withstand drought; immunity to fungus diseases; heavy tonnage per acre; sweetness of juice; ratooning capacity; ease of extraction of the juice; purity of the juice; low percentage of glucose and non sugars.

CANE SOILS.

The classes of soils in Porto Rico are described in a previous bulletin of this station. (b) As a rule cane soils are largely made up of a heavy clay and vary in color from red to black. It is usual to plant low lands most of which border the coast, not because the soil in itself is better adapted to cane but on account of the moisture content. Cane requires a large supply of water for its best development and this should not only be ample but constant. (c)

With the present price of sugar there is a tendency to extend the planting of cane on the higher lands in those sections of Porto Rico having a heavy rainfall. In good seasons such plantings are proving profitable.

DRAINAGE.

The value and importance of drainage of cane lands in Porto Rico are well known and established. In fact, so generally is this practice followed that in many instances it is carried out when unnecessary. Often lands that are elevated and sloping have drains cut through them similar to low lands, with the result that much labor is wasted.

(a) Meded. Proefsta. Oost-Java, 4. ser., 1907, No. 29, pp. 137–143.
(b) Porto Rico Sta. Bul. 3.
(c) The Hawaiian Sugar Planters' Station Report for 1903 states that it took from 164 to 277 gallons of water to produce one pound of sugar. At the West Java Station (Verslag. Proefstat. Suikerriet, West Java, 1902, p. 92) it was found that the cane plant used 5 liters of water per day. Z. Kamerling at the same station (Meded. Proefstat. Suikerriet West Java, 1905, No. 87, p. 4) made some studies of the amount of water evaporated by the cane plant. The average results with 9 different plants 5 months old showed an evaporation of 1¾ liters of water per day. The amount evaporated depends upon the distribution of the roots, the physical condition of the soil, soil moisture, leaf surface, temperature and sunlight.

The system of drainage in Porto Rico is primitive, but of the kind it is exceedingly well done. It consists in cutting surface ditches to carry off the excess of water, leaving the cane in beds. These drains are made with a great deal of precision and skill. This system, however, is antiquated and expensive, for not only must these drains be cut whenever the land is planted, but they must be kept clean throughout the year.

For whatever crop is to be grown on many of these cane lands in the future drainage will be found necessary. Agriculture has now reached a stage in Porto Rico demanding a permanent drainage of the soils wherever it is needed. There is only one system, therefore, that is applicable in this case and that is tile drains placed beneath the surface. (a) That this system is a success, has been proven for many years and in the various countries of the world. The first cost is the serious aspect of the case, but when they are once laid the work is done and they will continue in operation for an indefinite period, if properly placed.

The first problem confronting the experiment station when it was located was the drainage of the low lands which were, as is usual, the best on the estate. Looking into the matter of tile it was found too expensive to bring them from the States not only because of the high freight but the breakage that would surely occur. It seemed advisable to make them on the farm. For this purpose a machine was purchased, costing $300.00. This made tile from 3 to 7 inches in diameter and was operated by mules. It has proven very efficient, and not only have low lands of the station farm been drained but a great many tile sold to planters who are realizing the value of this system on their cane lands. Three inch tubes one foot long can be made on this machine at the rate of 3,000 per day, and 4, 5, 6, and 7 inch tile at the rate of 1,500 per day. The principal cost in making the tile has been in the burning, wood being scarce and expensive. Counting the cost of the machine and all labor, the drainage of the station lands, consisting of about 48 acres, has cost $50.00 per acre. The advantages that have accrued are these: The expensive surface drains required every year are unnecessary; the land is in better tilth and it can be worked sooner after rains. Further advantages which have been proven by careful experiments are that lands tile drained withstand drought better because of the fact that they are made more open and moisture can come up from below.

These drains have been in operation for five years and in that time have given no trouble except the necessity of an occasional cleaning of the mouth. In only two instances have tile broken in the lines and had to be replaced, occasioning only a few hours work. When a tile breaks the land falls in, making a hole, readily indicating the damage, which can be easily repaired.

The absence of surface drains permits the whole area to be cultivated and with greater ease.

(a) See U. S. Dept. Agr., Farmers' Bul. 40.

PREPARATION.

The cane lands of Porto Rico have been cultivated for many years. In all that time the plowing has only skimmed the surface. The cultural superintendent of one of our large centrals made the statement that in all their operations nothing had given them greater returns on the investment than steam plowing the lands to a good depth. All can not secure steam plowing, but better plowing than is usually the case can be done. A subsoil plow following the breaking plow in the same furrow can do much good. Not only does plowing prepare the land but it lets the air in, which is important.

The ordinary mold board plow has given best results on the heavy clay lands of the station. The disk plow has not proven effective, especially as the lands are usually covered with grass.

The well tested plows and cultivators are as a rule best. The average planter can not afford to risk money in trying out new implements. All tools used in cane cultivation should be strong and well made. The implements used in the cultivation of corn in the North are as a rule not strong enough for cane.

In breaking ground for cane it appears under present economic conditions in Porto Rico that cattle can be employed more cheaply than mules, for two reasons: First, because cattle live on the coarse grasses of the country and can therefore be maintained at less expense, and second, because of their ability to withstand rough treatment. The laborers of the country are used to cattle while the use of mules is new to them and the latter will not thrive on the rough treatment given to work animals in the field. On the other hand, mules have an advantage in cultivating cane. One man can handle one mule with plow while with an ox two are required, one to lead the animal and one to hold the implement. In any case the main point is in the care of the animals. A planter using mules must be prepared to give them good treatment and some grain feed. Some losses have occurred with mules from glanders and with cattle from anthrax. Both diseases can be prevented.

After the cane is growing frequent cultivation is advisable. This is especially so to destroy weeds and grass and in dry weather to conserve moisture by keeping a dust mulch on the surface. The successful methods worked out in corn growing can in most cases be applied to cane, which belongs to the same family.

PLANTING.

TREATMENT OF SEED.

Too little importance is given in Porto Rico to seed selection in planting. Old run out fields are very often used as sources of seed for planting. Like begets like is a world wide truth and it is folly to expect inferior cuttings to give the best results. While it is a fact that a cutting is more apt to

come true than a seed yet the plant in the former case has a better chance when propagated from a strong vigorous cutting.

The top joint has been found by trial at the Louisiana Station and at the British Station in Guiana to be best for planting. This is borne out by our experience in Porto Rico. Moreover, it is a part of the cane not ground and is therefore less expensive as seed.

All cane seed should be treated before planting. Excellent results have been obtained at this station by soaking the seed 24 hours in lime water. The seed is put in a tank, water run in and a few shovelfuls of lime thrown on. By comparison in the field such canes have germinated more readily and have been freer from disease.

All imported canes have been treated with Bordeaux mixture to avoid the introduction of disease from other countries. This should be practised in all cases in Porto Rico with all canes. The germination can be greatly improved and disease checked. The cost of such treatment is small while the benefits to be derived are great. (a)

METHOD OF PLANTING.

It is the usual custom in Porto Rico to plant cane in holes cut with spades. As our labor is annually becoming scarcer and wages increasing it will be necessary to employ some method with machinery to lessen the cost of the present method. Moreover, it appears that more efficient methods can be found not only lessening the cost but increasing the yields. Furrows laid open with the plow are made at a lower cost than holes dug by hand labor.

An experiment was made at this station comparing the hole with the furrow method. In the first plat three seed were planted in holes 7½ feet apart; in the second an equal amount of seed were planted 2½ feet apart in furrows; in the third plat the seed were planted in a continuous row horizontally and wholly covered. The yields of cane per acre were as follows:

	TONS.
In holes	36.6.
In furrows, seed on end	49.8.
In furrows, continuous row, covered	54.1.

The canes planted in continuous rows and covered were damaged somewhat by changas, so that it was necessary to replant some few spots.

At Central Aguirre a series of experiments were carried on to determine, first, the difference between Cristalina and Otaheite cane, second, a comparison of the Porto Rican and Hawaiian methods of planting, and third, the influence of certain kinds and amounts of fertilizers. Two and $\frac{24}{100}$ acres of land were used in these experiments. The Otaheite cane gave a yield at the rate of 49.76 tons per acre and Cristalina 60.56 tons, when planted

(a) Directions for making Bordeaux mixture can be found in Porto Rico Sta. Bul. 7.

in the Porto Rican style, that is, putting the seed in holes. By the Hawaiian system in continuous furrows the Otaheite cane gave 50.36 tons per acre and the Cristalina 71.48 tons. This is a difference in favor of the Hawaiian system of $\frac{6}{10}$ of a ton per acre with the white cane and 10.92 tons with the Cristalina cane. Estimating the amount of sugar produced from the samples analyzed the Hawaiian system gave 406 pounds more of sugar per acre with the Otaheite cane and 407 pounds more with the Cristalina cane. The cost of planting in the two cases is not given.

At the Burdwan Experimental Farm in India in 1902 (a) a comparison was made between furrow planting and trench planting. The former gave 24.5 tons of cane per acre and the latter 31 tons.

From the experience of various planters which is leading already to the change in methods it seems more profitable to substitute furrow for hole planting of cane in Porto Rico. The depth of the furrow depends upon rainfall. On the irrigated sections or where the lands are tile drained deep furrows or trenches promise the best results. These will not only keep the roots of the cane nearer a regular supply of water but will conserve water in irrigating. In regions of heavy rainfall and were the drainage is not of the best too deep furrows are inadvisable as they might during protracted wet spells hold water until the cane is drowned out.

DISTANCE OF PLANTING.

In distance of planting cane the prime object is to obtain the greatest amount in a given area and with least cost. A series of experiments were carried out with a total of 81 plats of $\frac{1}{20}$ of an acre each for the purpose of determining the amounts of cane produced when planted 10 by 10 feet, 7½ by 7½ feet and 5 by 5 feet. These plantings were made in series of three plats each adjoining each other. The preparation was the same in each case and the cultivation similar as far as the nature of the planting would permit. The wide planting necessarily permitted of longer cultivation than the narrow planting, not only with plows but also with hoes. In estimating the results it should be borne in mind that the wider the planting the greater the expense necessary in bringing the crop to maturity. This is by reason of the fact that grass and weeds grow longer in wider plantings than in the narrow ones where the ground is sooner shaded. The following tables show the results for two years. Each instance represents the average amount of cane grown on 27 plats:

(a) Ann. Rpt. Burdwan Expt. Farm (India), 1901–2. p. 9.

FIG. 1.—GREEN MANURING EXPERIMENTS. SWORD BEANS.

FIG. 2.—GREEN MANURING EXPERIMENTS. COWPEAS.

Comparison of distances in planting cane.

	Distance	Yield per acre.
	Feet.	Tons.
Plant cane	10 by 10	32.4
Do	7½ by 7½	37.0
Do	5 by 5	40.7
Ratoon cane	10 by 10	26.0
Do	7½ by 7½	30.9
Do	5 by 5	33.3
Total for 2 years	10 by 10	58.4
Do	7½ by 7½	67.9
Do	5 by 5	74.0

It will be seen that in every instance the narrow planting gave the largest yield not only for the plant cane but the ratoons.

The following table shows the results of close and wide planting where different amounts of fertilizers were applied:

Effect of fertilizers on yield of cane.

	Yield of cane planted at distances of		
	10 by 10 feet.	7½ by 7½ feet.	5 by 5 feet.
	Pounds.	Pounds	Pounds.
Heavy fertilization:			
Plant.....	33,230	39,580	46,025
Ratoon	19,750	28,050	33,765
Medium fertilization:			
Plant.....	30,475	32,145	36,875
Ratoon	24,260	30,225	33,580
Light fertilization:			
Plant.....	23,775	28,225	26,990
No fertilization:			
Ratoon	26,230	25,120	22,520

The cane plant has a comparatively small root system for the heavy growth above ground. The roots are very much in a bunch below the plant and provided there is abundant plant food present the roots do not extend very far. Our results show that close planting is more profitable not only in giving large yields of cane but economy in cultivation. The more the ground is shaded the less tendency there is for the grass and weeds to grow.

The differences in the yield in wide and narrow planting are greater where heavy fertilization is practised. The more abundant the plant food in the soil the closer the cane should be planted. When the plant food is deficient the cane plant must have a wider range for its roots in order to obtain the elements necessary for its growth. The results of 81 plats in this experiment indicate strongly that in Porto Rico in order to obtain the greatest profit we should plant close and fertilize heavily.

At the Cuba Experiment Station a number of experiments were carried on by F. S. Earle (a) on distance of planting. The usual system there is to plant in hills about 3 feet apart with a distanee of 4½ to 5 feet between the rows. The soil is prepared and cultivated the first season, but no further tillage is given. In the so called Zayas system wider planting is followed, usually 9 by 12 feet, and continuous cultivation is given throughout the year with modern implements. Stable manure is used but no commercial fertilizers are applied under this system, and when harvesting all canes that are not ripe are allowed to remain for continued growth. The Zayas system proved to be more costly and to give a smaller crop than the usual method of planting. Also, leaving the unripened canes proved unsatisfactory. Results obtained by cane planters in other parts of Cuba showed that the Zayas system does not always give as good yields the first year as the usual system. Some of this is due to injuries to the roots caused by continuous cultivation.

At the Queensland Sugar Station (1905-6) (b) cane from rows planted 4 feet apart gave 20 tons per acre more than cane from rows 7 feet apart. This difference was gradual between these two distances. The wider the rows apart the lower the yield. The cane from rows 4 feet apart gave 11⅓ tons of sugar per acre, while the cane from the rows 7 feet apart gave 9 tons.

IRRIGATION.

In considering the question of growing cane in Porto Rico there are two important features to be considered. One is the presence of too much water, and the other is the presence of too little. On the south side of the island the planter is confronted by the problem of too little water. Many of these soils are very fertile. Owing to lack of rain and irrigation not much of the fertility has been removed. The supply of water for these areas therefore takes precedence over all other questions. Some of these lands

(a) Estac. Cent. Agron. Cuba Bul. 2.
(b) Ann. Rpt. Queensland Bur. Sugar Expt. Stas., 6 [1905–6], p. 38.

are alkaline and of the nature that require gypsum to counteract their noxious influence. Water and drainage where possible would also very greatly help these lands. Fertilizers are not advisable in a great many instances owing to the fact that there is not enough moisture to enable the plants to absorb them. These conditions are quite different from those prevailing in the east, north and west sides of the island. Here the matter of drainage assumes the greatest importance. The excess of water must be removed either by surface drains or tile. At the experiment station at Mayaguez the rainfall is usually ample but it some times occurs that irrigation especially with young cane will give good results. In an experiment on one acre irrigated during the dry months of spring the yield was 40.5 tons of cane per acre while on another acre not irrigated the yield was 38 tons per acre.

The appropriation by the legislature of three million dollars to establish irrigation plants on the south side of the island will result in great good. The general plan is to divert certain rivers for that purpose. Many private irrigation enterprises are already in operation. The methods employed are various. Water is raised by electric and gasoline pumps, by gas and wind mills, and by gravity through canals from rivers and brooks. From a monthly estimate of one of the large centrals the cost of irrigation water raised by electric pumps varied from 1.2 censt to 2.5 cents per thousand gallons, by gasoline pumps from 1 cent to 2.1 cents per thousand gallons, gas mills 1.2 cents per thousand gallons. The cost per acre for irrigation through the month varied from $2.10 to $6.05.

In the report from the Queensland Sugar Station (1905 6) (a) it is stated that where canes are irrigated too much the purity of the juice is lowered, also that manures on irrigated and non-irrigated plats, while increasing the production of the cane, lowered the purity of the juice. There were exceptions, however, and upon land very much exhausted the application of mixed manures often improved the quality as well as the yield.

In irrigation experiments in Hawaii in 1905, C. F. Eckart (b) found that the different varieties of cane did best with different amounts of water. In general, the largest yields were obtained where the canes received from two to three inches of water per week. One inch of water per week produced 134,491 pounds of cane per acre, two inches 160,395 pounds, and three inches 177,906 pounds. The general average for two varieties and two crops shows but a small difference in yields of cane between the plats receiving two and three inches per week, while the largest yields of sugar as a rule were obtained with the heaviest yields of cane in two instances. Owing to a lower percentage of sucrose in the juice plats giving the largest yields of cane did not produce the largest yields of sugar. The average results with plant and ratoon crops of one variety showed a distinct loss when three inches instead of two inches of water were used. The results

(a) Ann. Rpt. Queensland Bur. Sugar Expt. Sta., [1905–6], p. 29.
(b) Hawiian Sugar Planters' Sta., Div. Agr. and Chem. Bul. 14.

in general showed the different water requirements of two varieties and the necessity for more trials.

FERTILIZATION.

FERTILIZER REQUIREMENTS OF PORTO RICO SOILS.

There is hardly a field in Porto Rico devoted to cane culture that will not be benefited by an application of fertilizer. On the other hand, fertilizers may fail to give any result and again may occasion losses not only of the fertilizer itself but by decreasing the yield of cane. In agricultural practice the most difficult thing to determine is the proper use of fertilizers on a given soil. In all the studies made on this subject no definite rules have been formulated. The idea is popularly held that by making a chemical analysis of a soil we can tell what it needs in the way of fertilizers, but this is not so. The elements needed by a plant may be found in a soil and at the same time be in such condition that the plant cannot secure them. They may be locked up in some chemical combination or else the physical condition of the soil such that the plants cannot use the supplies present. Before the growing crop can utilize the fertilizers applied as well as the elements present the soil must be in good physical condition, that is, in a state of tilth. Therefore, in any proper scheme of fertilizing cane we must go farther back and see to the physical condition of the field.

It is the most difficult thing in scientific agriculture to advise a planter in regard to fertilizing his soil. With all knowledge available it is still an uncertain practice. Much study of soil problems is necessary before we can ever get upon a definite basis for fertilizing. There are many factors to take into consideration and a great many points that influence the growth of plants to be worked out. During the last century a beginning only was made. It was found that of the fifteen or sixteen elements that enter into the composition of plants three as a rule are deficient in soils. These are nitrogen, phosphorus and potash. Later researches have sought to determine the relation of other elements to plant growth. It is well known that lime has much to do with the best plant production and also that the relation of this to other elements as magnesia influences the productivity of a soil.

Of increasing importance is considered the physical condition of the soil. The improvement of the tilth has long been apparent as greatly influencing the amount of the crop. Also it has been determined that the physical condition has much to do with the ability of the plant to utilize fertilizers which are applied. If a soil is in bad physical condition such as being compact and hard, it is evident that this must be improved before the plant can utilize any amount of fertilizer. Also the importance of drainage enters in, and under other conditions the proper application of irrigation water.

Every planter should make a study of his individual soils. He should

devote himself to systematic experiments in increasing the yields of his crop A method for carrying this out has been explained in a former publication. (a)

Porto Rico agriculturally speaking is an old settled country. The resources of the island have been greatly exploited. Four hundreds years ago the Spaniards were taking out the gold and in doing this nearly wiped out the native population and so completely took all the gold that there is practically none produced at the present time. During the past 400 years almost as stringent efforts have been made in extracting by means of continuous cropping, the nitrogen, phosphorus, and potash of the soils. When we take into consideration the amounts of these elements that have been shipped out of the island in coffee alone some idea can be had of the need of our soils in regard to the fertilizing elements. The only wonder is that they are as productive to-day as they are. This is undoubtedly due to the wonderful natural strength of the soils of Porto Rico.

There are two general conditions of Porto Rican soils to deal with before applying fertilizers; they are irrigation and drainage. In the dry sections deficient in rainfall, in the absence of rain for the growing crop irrigation must be practised. Otherwise the fertilizers will remain undissolved in the soil and not be available to the plants. Again in sections of heavy rainfall the soil is often water-logged and so compact that the plants cannot extend their roots and absorb the fertilizers that may be applied. On the south side of the island in the dry section on good land where cane has not been grown for many years, applications of fertilizers will probably not be profitable for the first crop nor perhaps for the second or third. These soils, however, need treatment besides irrigation water. In some cases drainage is necessary in order to carry off certain noxious alkali salts, which otherwise would accumulate in the surface soil. In many places where the alkali is so strong that cane will not grow it is advisable to apply 500 to 1,000 pounds of unburnt gypsum per acre. This will counteract the alkali present and render these soils very fertile. Sometimes irrigation water contains alkali and it is necessary where this is applied that drainage be provided in order to again eliminate these salts from the soil. Where fertilizers have been applied to such soils and no good crop of cane has resulted, owing to scarcity of water, it is not advisable to apply fertilizers again until a good crop has been secured, as the amounts formerly applied remain undissolved in the soil. In the heavy clay soils where the rainfall is ample it is again highly necessary to bring the land into a better tilth before adding large amounts of fertilizer. The practices necessary for this are cultivation and the application of burnt lime. The cultivation of such soils should be done during the dry periods so that the grass will be killed, the clods broken up and the soil aerated. The application of burnt lime will assist very materially in mellowing such lands and preparing them for the condition most conducive

(a) Porto Rico Sta. Cir. 6.

to the production of cane. On many lands of this nature in Porto Rico no results have been obtained with the use of fertilizers. This is doubtless due to the fact that the soils are in such poor physical condition that the cane cannot utilize to the best advantage the fertilizer added. Before large amounts of money are spent on fertilizers these soils should first be brought into the best physical condition by better cultivation and liming.

The sugar cane is a crop of heavy tonnage. Moreover, with our modern system of growing it the crop is, as a rule, shipped to the mills and with most planters none of it is returned to the land. It is very evident, therefore, that continual cane cropping will exhaust the soil of its fertility. Porto Rico is an old cane-growing country and nearly all the lands devoted to this crop have been pretty well worked out. Under such conditions fertilizing must be practised in order to produce profitable crops of cane.

Considering the amount of the growth of the cane plant above the ground its root system is comparatively small. This is often proven by cane failing, the roots not being sufficiently extended to hold it upright. By examining a stool of cane it will be found that there is a large amount of roots within a very small area. This will give us some indication as to the best manner of applying fertilizers. The larger part of the fertilizers should be close to the plant. In other words, the hole or row application is best. Moreover, it will be noticed that when the rain falls the water is caught by the leaves of the cane and carried down to the roots. It is better, therefore, to have the larger part of the fertilizer near the stalks where it will be reached by the water dissolved and carried down to the roots of the plant.

In general it may be said that all the cane soils of Porto Rico will yield a profit on the application of fertilizer. The question that confronts us is to determine the kind and the amount of fertilizer to apply. This each planter must in a measure determine for himself, unless his nearby neighbour has found out the facts from fields very similar. On experiments carried out during three years at the experiment station it has been fairly demonstrated that our soils need the three elements of the fertilizer, namely, nitrogen, phosphorus, and potash, and are also benefited by an application of burnt lime. From studies of the cane on 90 plats the results were varying, as is always the case in fertilizer experiments. Conclusions cannot be drawn from a few trials but from the average of many. Sometimes on plats adjoining but treated under equal conditions and amounts of fertilizers applied the results have been reversed. From present knowledge of the subject of fertilization these cannot be explained.

RESULTS OF FERTILIZER EXPERIMENTS IN PORTO RICO.

It will not be attempted to give in detail the results of our experiments during three years with 90 plats. The following table will show the percentages of increase with the different kinds of fertilizer. Marking the yield of the check plats as 100 the yields of those to which nitrogen, phophorus,

and potash were added, singly and in combination, are shown with the amounts greater than 100. Each single experiment was repeated twenty times, so that the average would become more exact.

Percentage increase due to fertilizers.

Plat No.	FERTILIZER	Plant cane	Ratoon cane	Total
		Per cent.	Per cent.	Per cent.
1	No fertilizer	100.00	100.00	100.00
2	Nitrogen	112.51	110.79	111.75
3	Phosphorus	108.07	111.70	109.66
4	Potash	110.31	118.99	114.11
5	Nitrogen and phosphorus	117.10	119.56	118.18
6	Nitrogen and potash	115.98	123.74	119.38
7	Phosphorus and potash	108.01	119.65	113.29
8	Nitrogen, phosphorus, and potash	105.33	124.29	113.63

As with all plat work with fertilizers the results are far from exact or uniform. In all cases an increased crop resulted but no rule can be drawn from the figures that will hold good. It appears that at the station where the lands have rested for some years ratoons need fertilizers more than plant cane and that for these a complete fertilizer is best.

LIMING CANE SOILS.

Lime is a necessary constituent of plants. It is in nearly all instances found in sufficient amount in the soil for the direct needs of the plant. It is not, however, always in the correct proportion for the best growth of the crop nor for the best physical condition of the soil. The amount of lime has a great deal to do with the physical condition of agricultural soils. It is a well-known principle in agriculture that lime renders the soil more mellow and heavy clay soil especially more easily worked. It also plays a very important part in rendering available for the needs of the plant some of the other elements of fertility.

The heavy clay soils of Porto Rico are very much in need of liming, in fact, many of them need this element more than any other, not excepting those of the fertilizers. Lime applied has a two-fold object, one to render these soils more porous and easily worked and the other to neutralize the acidity which often develops in them. For such purposes burnt lime is the form necessary and this may be obtained in nearly all sections of Porto Rico. The cost varies in different localities. Where one has a kiln and burns his own lime the cost is about $5.75 per ton. To buy it and haul it some distance, as is the case at Mayaguez, it is worth about $8.00 per ton.

Again, some of our alkali soils will be greatly benefited and made productive by applications of calcium sulphate or unburnt gypsum, a form of lime which is found in natural deposits in other countries and which can be bought in New York at about $7.00 per ton.

At the station a series of experiments was carried out during two years in applying lime to cane. The following table shows the results with 54 plats to which lime was applied at the rate of 320 pounds per acre. This was freshly burnt lime and was applied just before the cane was planted:

Comparison of results of test with and without lime.

Yield per acre of cane planted at distances of

	5 by 5 feet.	7½ by 7½ feet.	10 by 10 feet.
	Tons.	Tons.	Tons.
Fertilized and limed:			
Plant cane.....	51.1	44.0	36.9
Ratoon cane...	37.5	31.2	22.0
Total, 2 years	88.6	75.2	58.9
Fertilized, unlimed;			
Plant cane.....	41.0	35.7	33.9
Ratoon cane...	37.3	33.6	27.0
Total, 2 years	73.98	65.48	57.47
No fertilizer;			
Plant cane.....	30.0	31.4	26.4
Ratoon cane...	25.0	27.9	29.1
Total, 2 years	55.0	59.3	55.5

The lime on these plats cost $1.28 per acre and averaging the values of the canes produced the limed plats gave an increase in value over the unlimed of $7.15 per acre, being a net profit of $5.87. It will be noted from the figures in the table that on limed plats the ratoons fell below in yield those on the plats not limed. This shows that by liming we get a largely increased crop the first year by reason of the fact that the lime renders available the plant elements in the soil to the detriment of the succeeding crop. The experiments also showed that the limed plats gave much greater yields where the largest amounts of fertilizers were added. If we continue to lime our land we must also continue to fertilize in order to get the greatest profits. Heavy clay lands, such as those at the experiment station, need first a heavy application of burnt lime. After that each year there should be a heavy application of a complete fertilizer with nitrogen as the principal element.

In another experiment on station clay land the yields of cane per acre were as follows:

	TONS.
3,000 pounds lime per acre	69
500 pounds lime per acre	50
Without lime	44
3,000 pounds lime with fertilizer	62
500 pounds lime with fertilizer	57

This experiment indicates that the clay lands of the station used in growing cane need first liming and second fertilizing.

There are found in some sections of Porto Rico immense deposits of soft coral limestone. In some instances this has been used on cane lands with apparently beneficial results. While the effects are not as evident as with burnt lime, in some instances where the transportation is not expensive a trial of it is warranted.

At this station a very wet swampy piece of land was tile drained and planted to cane. It was divided into three plats and the cane planted 10 by 10 feet. To one plat there was applied to each hill of cane five gallons of burnt lime and to another five gallons of soft unburnt lime. The yields per acre were as follows:

	TONS.
Burnt lime	56.1
Uuburnt lime	39.8
No lime	24.9

A bulletin of the Hawaiian Sugar Planters' Station (a) gives the results of the application of lime in the form of ground coral and gypsum. Where these were applied a better showing was made in regard to density, sucrose, glucose, and purity than where no lime was added. The gain in the sugar of the cane where the ground coral was applied was 46.6 per cent, and with gypsum 46.9 per cent compared with the plat that was not limed. These were added to soils that were irrigated with saline water.

EXPERIMENTS WITH BAT GUANO.

In many parts of Porto Rico caves abound that contain large deposits of bat guano. These are variable in composition but some of them are very rich, running over 20 per cent phosphoric acid. Many Porto Rican soils are very deficient in phosphorus and to such these deposits are especially valuable.

In an experiment with cane three plats where laid off. To one was added a shovelful of bat guano, to another a shovelful of lime, and to the

(a) Hawaiian Sugar Planters' Sta., Agri. Div. Bul. 11.

third nothing. The hills of cane were 5 by 5 feet and the guano and lime was worked into the hill. The guano plat gave 40½ lbs. cane to the hill while the lime and blank plats gave only 33 lbs. cane to the hill. This was a difference in favor of the guano plat of 6½ tons of cane per acre.

In another experiment cane planted 5 by 5 feet was treated as follows:

To plat Nº 1 there was added to each hill of cane one liter composed of guano one half and burnt lime one half; Plat Nº 2 one liter of guano; Plat Nº 3 one liter of lime; Plat Nº 4 check.

The yields were as follows:

	Tons per acre:
Guano and lime	42.7
Guano	47.6
Lime	43.6
Check	36.0

EXPERIMENTS IN DIFFERENT PARTS OF PORTO RICO.

A number of experiments in fertilizing cane have been carried out in different sections of Porto Rico. These have been with the object of studying the needs of the soils in different parts of the island. Some have been in cooperation with the station and others have been carried out by sugar planters and centrals.

The following plan with formulas was tried in various sections:

Yields obtained with different fertilizer formulas at the experiment station, Mayaguez.

Plat No.	FERTILIZER PER ACRE	Yield of cane per acre
		Tons.
1	Tankage, 200 lbs.; sulphate of ammonia, 100 lbs.; acid phosphate, 450 lbs.	33.8
2	Dried blood, 140 lbs.; sulphate of ammonia, 100 lbs.; muriate of potash, 250 lbs.	31.2
3	Muriate of potash, 250 lbs.; acid phosphate, 450 lbs.	22.5
4	Tankage. 200 lbs.; sulphate of ammonia, 100 lbs.; muriate of potash, 250 lbs.; acid phosphate, 450 lbs.	28.0
5	No fertilizer.	23.1

From the above results obtained at the experiment station on ratoon canes it is evident that nitrogen is the element most needed. The results with potash and phosphorus are lower than with no fertilizer, indicating that it is not advisable to use these elements singly or together, but one or both could likely be used profitably with an application of nitrogen.

The following experiments were made at the Hacienda San Francisco, Hormigueros:

Yield obtained with different fertilizer formulas at Hormigueros.

Plat No.	FERTILIZER PER ACRE	Yield of cane per acre
		Tons.
1	Lime, 800 lbs.	18.75
2	Nitrate of soda, 250 lbs.; sulphate of ammonia, 200 lbs.; acid phosphate, 600 lbs.	18.47
3	Nitrate of soda, 250 lbs.; sulphate of ammonia, 200 lbs.; sulphate of potash, 250 lbs.	20.87
4	Sulphate of potash, 250 lbs.; acid phosphate, 600 lbs.	19.05
5	Nitrate of soda, 250 lbs.; sulphate of ammonia, 200 lbs.; sulphate of potash, 250 lbs.; acid phosphate, 600 lbs.	19.80
6	Nitrate of soda, 250 lbs., sulphate of ammonia, 200 lbs.; sulphate of potash, 250 lbs.; acid phosphate, 600 lbs.; Lime, 1,000 lbs.	21.37

From the above results obtained at Hormigueros it is apparent that soils in that vicinity are not in the proper physical condition to give the best returns from an application of fertilizers. It will be noted that the yield from the application of lime is almost equal to those were heavy applications of fertilizer were made. It is evident in this case that these soils should be heavily limed to improve their physical condition and to bring them to the proper tilth. After this, fertilizers will be advisable, starting with small amounts and with those especially strong in nitrogen. It is also likely that the drainage could be improved, and it is very probable that these soils are acid in their action.

The following results were secured on experimental fertilizer plats at Santa Rita:

Yields obtained with different fertilizer formulas at Santa Rita.

Plat No.	FERTILIZER PER ACRE	Yield of cane per acre
		Tons.
1	No fertilizer	31.65
2	Tankage, 400 lbs.; nitrate of soda, 400 lbs.; acid phosphate, 410 lbs.	29.10
3	Dried blood, 290 lbs.; nitrate of soda, 400 lbs.; sulphate of potash, 240 lbs.	29.
4	Sulphate of potash, 240 lbs.; acid phosphate, 600 lbs.	27.30
5	Sulphate of potash, 400 lbs.; nitrate of soda, 400 lbs.; acid phosphate, 410 lbs.	31.15
6	Tankage, 400 lbs, nitrogen, 9.8 per cent and phosphoric acid, 3.2 per cent.	45.10

The above results obtained at Santa Rita indicate that on the soils under experiment very heavy applications of fertilizers with the land in its present condition is inadvisable. The amounts applied, namely 800 to 1,200 pounds per acre, were excessive in all cases except the last, showing a loss in tonnage compared to the plat where no fertilizer was used. In the case of plat 6 nitrogen was in the form of tankage, which doubtless disintegrated gradually during the growing period and afforded the nitrogen as needed and not in a large amount at once as is the case with quick acting manures.

The results of fertilizer experiments at Central Ingenio, near Yabucoa, were as follows:

Yields obtained with different fertilizer formulas at Central Ingenio.

Plat No.	FERTILIZER PER ACRE	Yield of cane per acre
		Tons.
1	Nitrate of soda, 180 lbs.; sulphate of ammonia, 180 lbs.; acid phosphate, 360 lbs.	42.36
2	Nitrate of soda, 180 lbs.; sulphate of ammonia, 180 lbs.; sulphate of potash, 150 lbs.	43.98
3	Sulphate of potash, 150 lbs.; acid phosphate, 360 lbs.	44.22
4	Sulphate of ammonia, 180 lbs.; nitrate of soda, 180 lbs.; sulphate of potash, 150 lbs.; acid phosphate, 360 lbs.	42.72
5	Nitrate of soda, 90 lbs.; sulphate of ammonia, 90 lbs.; sulphate of potash, 75 lbs.; acid phosphate, 180 lbs.	45.36
6	No fertilizer	42.72

The whole field gave an average yield of 33.98 tons per acre. The results show that in the application of fertilizers in only plats 3 and 5 is there any appreciable increase in the yield while plats 1, 2, and 4 show little or no increase over 6 which had no fertilizer.

The fertilizer experiments conducted at Central Merceditas, near Ponce, resulted as follows:

Yields obtained with different fertilizers at Central Merceditas.

Plat No.	FERTILIZER PER ACRE	Yield of cane per acre
		Tons.
1	No fertilizer	40.7
2	Nitrogen and phosphorus	40.9
3	Nitrogen and potash	41.3
4	Phosphorus and potash	41.3
5	Nitrogen, phosphorus, and potash	41.6
6	Nitrogen, phosphorus and ½ potash	41.2

From the above results obtained at Central Merceditas it is evident that the soils do not need fertilizer in their present condition, as in no case was a sufficient profit obtained by their use. These canes were grown under drought conditions, and had there been plenty of water doubtless the fertilizers applied would have shown better results. It is evident that if fertilizers are put in the ground and there is not sufficient water to dissolve them the plants cannot make sufficient growth to utilize the plant food added. It emphasizes the fact that before a fertilizer can be profitably employed in growing cane the physical condition as regards tilth and moisture must be carefully looked after.

At Central Aguirre a number of tests of fertilizers were made which were very variable. Where large amounts were used the results obtained indicate a loss in value and in some cases a decrease in yield. It is evident that these soils under the conditions of cultivation and the application of water did not respond to heavy applications of fertilizer. The plats treated with 500 pounds of a fertilizer made up of sodiun nitrate, ammoniun sulphate, potassium sulphate, and superphosphate showed an average loss of yield in comparison with the plat receiving no fertilizer. The application of 1,000 pounds to the acre of the same showed a slight gain in tonnage. The addittion of 1,500 pounds of this mixture per acre showed a distinct loss in tonnage compared with the check plats. Averaging all plats, those unfertilized produced more than the fertilized plats. Not only was the fertilizer thrown away but it actually produced a loss in tonnage. The average yield of the plats was at the rate of 58 tons per acre. Had the soils been in better physical condition they probably would have with the fertilizers produced a greater yield. There

was a lack or an excess of water, a compactness of the soil, an excess of noxious salts or some other unknown factor that kept the cane from profitably utilizing more of the fertilizing elements that were applied to the soil.

The Guanica Centrale carried on a number of experiments during 1908 with nitrogen in various forms. The applications were made in equal amounts of fertilizer per acre without reference to the percentage of nitrogen. The following table shows the rank of the different fertilizers as regards the yield of sugar per acre:

Effectiveness of different forms of nitrogen.

FERTILIZER	1st. Experiment	2nd. Experiment	3rd. Experiment	4th. Experiment	5th. Experiment
Nitrate of soda	2	3	2	4	3
Sulphate of ammonia	3	2	4	1	2
Tankage	1	1	3	3	1
Cyanamid			1	2	

The condition of the soil probably has much to do with the effectiveness of the form in which nitrogen is combined in the fertilizer. Where the rainfall is abundant and well distributed a slowly available form will likely prove best. If on the contrary there is a scarcity of water or if it is applied at long intervals a quickly available form will give the highest results. Sometimes the element with which the nitrogen is combined will add something to the favorable results, as the phosphorus in tankage and the lime in cyanamid.

RESULTS IN FRENCH WEST INDIES.

Besides the numerous fertilizer experiments made in the soils of Porto Rico it will be advisable to consider the results obtained in other countries, especially those islands of the West Indies where the soils are somewhat similar to the Porto Rican soils. Perhaps the longest cropped soils of the West Indies are those of Martinique, which has long been famous for its sugar and rum. The lands about the port of Fort-de-France, which is not in the volcanic district of the island, resemble those of Porto Rico. They are for the most part clay, varying in color from red to black. Cane production has been carried on for a great many years not only in the low lands but covering the well watered hills. The French cultivators are famous for the care they give their fields and this is shown in their colonies. Heavy fertilizing has been found profitable and many tons of fertilizers are imported annually into the island. It has been found that those soils require the three elements of the fertilizer, nitrogen, phosphorus, and potash, and especially the former.

The application of burnt lime has also been found profitable. In the island of Guadeloupe the same conditions prevail. The eastern part of that island has been devoted for a great many years exclusively to cane. The soils are greatly benefited by liming and require also a complete fertilizer.

RESULTS IN BRITISH WEST INDIES.

The English island of Barbados possesses a black soil overlying coral limestone that is different from the soils of Porto Rico. This layer of soil is thin, in some places the rock showing through. Besides this they have a soil which is more like the clay soils of Porto Rico. The black soils need nitrogen and potash but not phosphorus. Experiments with fertilizers on cane have been carried on in Barbados for a number of years. The results have shown considerable differences in different seasons and different localities. Nitrogen seems the most important ingredient of the fertilizer required by the various soils. In the majority of cases phosphorus in the form of superphosphate or basic slag had little or no effect. Potash in most cases gave a profitable increase. The application of nitrogen, phosphorus and potash seemed to have no direct effect upon composition of the juice. The only benefit was in the increased growth of cane. However, when nitrogen was applied late it retarded the ripening and caused the production of a poor and impure juice. The application of lime gave an increase in the crop even where lime seemed to be abundant. This apparently was due to improvement in the physical condition of the heavy clay soils. The use of phosphorus and potash in addition to large applications of stable manure reduced the yield of cane. Where 35 tons of stable manure was used to the acre, commercial fertilizers in addition were not advisable. As a result of better tillage a gain of 2½ tons of cane per acre was made. Subsoiling, manuring, and cultivating all gave increased yields.

In the report of the Imperial Department of Agriculture for the West Indies, 1905-6, F. Watts (a) gives the results of experiments with plant canes for six years and with ratoon canes for five years. It was found that commercial fertilizers were unprofitable for plant canes on land well tilled and which had received about 20 tons of barnyard manure per acre. It was also found that with ratoon canes nitrogenous manures were essential to profit. Nitrogen in a quick acting form, such as nitrate of soda or sulphate of ammonia, should be given in one application at an early date in the growth of the cane.

In other experiments the kind of commercial fertilizer had but slight effect upon the quantity of sugar in the cane. Nitrogen, phosphorus, and potash together gave a slight increase of sucrose per ton of cane. Nitrogen when used alone gave a slight decrease of the sweetness of the cane.

(a) Imp. Dept. Agr. West Indies, Sugar Cane Expts. Leeward Isl., 1905–6, pt. 2.

Manures, such as are used in ordinary practices in the Leeward Islands, have an influence of altering the weight of the cane per acre without profoundly altering the weight of sucrose to the ton of cane.

By using cuttings from canes of a high and of a low sugar content there was a gain of about 10 per cent of sucrose from the high sugar cuttings over those from canes of a low sugar percentage. Treating the seed with Bordeaux mixture tended to preserve the cane cuttings while in the soil and to increase the number of plants grown from the cuttings by 62 per cent.

RESULTS IN BRITISH GUIANA.

British Guiana has long been famous for its sugar production. Demerara crystals made from the old Bourbon cane were considered before the days of the sugar refineries as the very best and purest of sugars. The cane fields of this colony are quite extensive, having been developed to some extent by the Dutch long before the acquisition of the colony by the English. The soils of British Guiana are naturally very fertile, being alluvial deposits of the large rivers of South America. A great deal of work has been done by the British Botanic Station of Georgetown during 25 years and from this some very valuable lessons may be drawn for our work in Porto Rico.

As in Barbados, nitrogen appears to be the element governing the yield of sugar cane and is the most important in the fertilizers applied; sulphate of ammonia is considered preferable to nitrate of soda for the cane. From 200 to 300 pounds of sulphate of ammonia per acre proves to be the most profitable application of nitrogen. The experiments indicate that in British Guiana phosphates when applied to plant cane with nitrogen and potash will give increased yields. Phosphate when applied alone was not profitable nor was there any advantage gained when used with ratoon crops. The addition of potash had little or no effect. At the present time it seems that there is enough of this element set free in the soil to renderits application in fertilizers unnecessary. The use of lime gave largely increased yields. Its action seemed to be principally in improving the mechanical texture of the soil so that the plants could take up to better advantage the fertilizer applied and the land could be more easily worked.

Neither phosphoric acid, potash, nor lime affected the percentage of sugar in the juice, while nitrogen fertilizers retarded the ripening and reduced the sugar content. This, however, was more than offset by a larger yield.

RESULTS IN HAWAII.

In a number of cane-growing countries experiments have been carried on with the view of determining a rational method of fertilizing the soil. In the Hawaiian Islands fertilizers in cane growing have been used in the greatest amounts. Theirs is a volcanic soil that can absorb large amounts

of fertilizers and is in such physical condition as to permit the roots of the cane to extend great distances seeking for plant food. The greatest increase reported by the Hawaii Station with the use of fertilizers was 6,053 pounds of sugar per acre over land where no fertilizer was used. This was obtained with very heavy applications of fertilizers. On the other hand, in soils in poor physical condition the losses from the use of heavy application of fertilizers were very great.

C. F. Eckart, in fertilizer experiments in Hawaii from 1897 to 1905, (a) found that the highest purity in the cane, 90.69 per cent, was obtained on the unfertilized plats and the lowest, 88.29 per cent, on the plats receiving a complete fertilizer with nitrogen in the form of sulphate of ammonia. The highest sucrose content, 18.26 per cent, was secured on the unfertilized plats and the lowest, 16.40 per cent, on the plats receiving a complete fertilizer with the nitrogen in the form of dried blood.

It was found that various varieties of cane took different amounts of plant food from the soil. This applies to nitrogen, phosphorus, potash, and total solid matter. It was also found that there was a variation in the chemical composition of the same variety during different seasons. The amount of the different elements taken up by the plant was apparently due to climatic conditions and changes in the soils, which are different during various seasons.

RESULTS IN VARIOUS COUNTRIES.

In 1903 and 1904 the United States Department of Agriculture carried on some experiments in the culture of sugar cane at Waycross, Georgia. (b) These canes were grown for the purpose of making sirups. The soil employed was a worn out sandy one very much in need of fertilizers. The most striking result was in the yields of cane obtained from land that had previously grown a crop of cowpeas The percentage of sucrose from the cane on the land that had grown cowpeas was 14.7 per cent while on that which had not grown cowpeas it was 12.31 per cent.

In a bulletin published in Indo-China by the French government in 1906 (c) fertilizer experiments were reported on soils very deficient in humus. Mineral fertilizers alone where of no value and small quantities of barnyard manure gave unprofitable results also. A heavy application of barnyard manure gave a somewhat smaller yield than a mixture of the same with commercial fertilizers, but the profit was greater. The author considers that the first need of such a soil is a supply of humus.

(a) Hawaiian Sugar Planters' Sta., Div. Agr. and Chem, Bul. 15.
(b) U, S, Dept, Agr,, Bur, Chem, Bul, 93,
(c) Bul, Econ. Indo-Chine, n. ser. No. 9 (1906), 53, pp. 629–635.

ONE OR MORE APPLICATIONS.

In the matter of applying all the fertilizer at one time or at different periods results vary. It depends largely upon the nature of the fertilizer. If it is one that is readily dissolved, results will be better if several applications are made. If on the other hand it is a fertilizer that dissolves slowly, one application made before the field is planted is best. At the Louisiana Station it was found that 24 lbs. of nitrogen per acre in a very wet season produced almost as much cane as 48 lbs.

In experiments at Central Aguirre a greater average was obtained applying the fertilizer all at one time rather than two applications. At the Guanica Central on irrigated land results of one and two applications of fertilizer were inconclusive. With some fertilizers one application gave best results while with others two gave the most profit.

At Waycross, Ga., in experiments carried on by the United States Department of Agriculture (a) in growing cane for the production of molasses, a number of fertilizer experiments were made. Dividing the fertilizers and making two or three applications as compared to applying it all at one time did not show a sufficient advantage to justify the practice.

PROFITS IN FERTILIZING.

In using fertilizers a planter should keep strict account of the cost thereof per acre and estimate as closely as possible after harvesting the crop whether the application has proved profitable or not. It is very easy to obtain an increased yield with fertilizers, but it must be remembered that such an increase is not always made with a profit. In the several hundred fertilizer experiments carried out with canes at the station in all cases an increase in the crop was obtained over plats where no fertilizer was used. Not, however, in all cases were such increases made with profit, for in some plats the cost of the fertilizer was greater than the value of the additional cane.

The land experimented upon at the station is very near the city of Mayaguez and has been in cultivation for a period of perhaps more than a hundred years. Continuous crops have been removed from this land and very little manure or fertilizer added. As would be expected it is naturally very deficient in plant food. In all cases each of the elements of the fertilizer gave an increased yield. With nitrogen a greater profit was made with plant canes than with ratoons, but the reverse was true with phosphorus and potash. In combination nitrogen and phosphorus and nitrogen and potash gave nearly average returns with both plant cane and ratoons. With phosphorus and potash in combination much greater

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(a) U. S. Dept. Agr. Bur. Chem, Bul, 103,

returns were made in applying the fertilizer to the ratoons rather than to the plant cane, and with a combination of nitrogen, phosphorus, and potash, much greater returns were made with ratoons than with plant canes. With plant cane on lands that had been in grass for a number of years, the increase in tonnage using nitrogen, phosphorus, and potash, was not equal to the value of the fertilizer used. The following table shows in a concise form the increase in tons compared with the check plats, and also the cost of the fertilizers applied:

Increase in yield compared with cost of fertilizers.

	Gain in yield per acre	Cost of fertilizer per acre
	Tons.	
Nitrogen:		
Plant cane	4.18	$ 4.40
Ratoon cane	2.81	" 4.40
Phosphorus:		
Plant cane	2.7	" 2.56
Ratoon cane	3.04	" 2.56
Potash:		
Plant cane	3.45	" 3.44
Ratoon cane	4.95	" 3.44
Nitrogen and phosphorus:		
Plant cane	5.72	"11.36
Ratoon cane	5.1	"11.36
Nitrogen and potash:		
Plant cane	5.35	"12 24
Ratoon cane	6.18	"12.24
Phosphorus and potash:		
Plant cane	2.79	" 8.56
Ratoon cane	5.11	" 8.56
Nitrogen, phosphorus and potash:		
Plant cane	1.78	"10.40
Ratoon cane	6.32	"10.40

The value of cane varies with the sucrose content and the price of sugar. At present it varies from $3.00 to $4.00 per ton at the mill.

STRIPPING CANE.

The question of the advisability of stripping cane is worthy of further study in Porto Rico. It is said that cane since the American occupation is stripped much more than it was formerly. The cane plant, like all others, needs its leaf surface for growth. Even after a leaf begins to dry it is probable that some substance is drawn from it by the growing cane stalk. It is undoubtedly true that in many fields in Porto Rico cane is stripped too close and the leaves are taken from the plant which are still valuable in promoting its growth.

In three series of experiments on the influence of stripping sugar cane made at the Hawaiian Sugar Planters' Station (a) it was found that in some cases the process was profitable while in others it was not. It probably depends upon the variety of the cane and the character of the season. In another experiment made at the station (b) the average yield of stripped cane was 68 tons per acre and unstripped cane 87 ton sper acre. The available sugar from the stripped cane was 8.99 tons per acre and from the unstripped cane 12.21 tons per acre. In both plant and ratoons the unstripped cane showed a higher percentage of sucrose in the juice and a higher coefficient of purity than the stripped cane.

LOSS OF WEIGHT IN SHIPPING.

From the records kept of 725,000 pounds of cane shipped from the experiment station at various periods and to different mills it was found that the loss in weight varied from 5.8 to 8 per cent. The cane was weighed at the station immediately after loading on the wagons. The loss ran fairly uniform with the various car loads. The difference in a few instances was slight, the loss by evaporation of juice apparently having been checked by rain on the open car of cane while in transit.

DETERIORATION BETWEEN CUTTING AND GRINDING.

When cane is cut and its growth thereby stopped there sets up very soon a deterioration in the quality. This is brought about by the action of certain ferments which are in the juice and that change the sucrose into glucose. This is the beginning of that fermentation which ultimately changes the sugar into acid. It is therefore advisable as soon as possible after the cane is cut to grind it. There is a loss to the planter in weight by its drying out and to the mill in sugar by the changing of the cane sugar into the less valuable molasses or glucose. The amount of this change depends upon the water content of the cane, the atmospheric conditions, and the degree of maturity.

To show the extent of this loss the following results reported by one of the centrals of Porto Rico are appended. A contract was made with a man to cut and load cane for the mill. When he began he put his men into the field and cut down at once a great deal of cane which he shipped during a period covering several days. Taking the results from this plantation as reported by the mill, the following figures are obtained:

(a) Hawaiian Sugar Planters' Sta. Div. Agr. and Chem, Bul, 16,
(b) Ibid, Bul 25,

Effect of delay in grinding on quality of juice.

Number of cars	WHEN GROUND	Average purity of juice
		Per cent
28	30 hours after cutting	88,13
23	36 hours after cutting	86,69
27	48 hours after cutting	86,32
27	3 days after cutting	86,28
33	4 days after cutting	85,22
28	5 days after cutting	85,59

These figures show a rapid deterioration in the value of canes after cutting.

In cutting cane from another plantation the following analyses were made:

Effect of delay in grinding on quality of juice.

Number of cars	WHEN GROUND	Average of purity in juice
		Per cent
56	12 hours after cutting	85,79
80	24 hours after cutting	85,17
71	48 hours after cutting	85,33
67	3 days after cutting	84,64
78	4 days after cutting	84,61
56	6 days after cutting	83,07

The average loss of these shipments owing to cutting some time before grinding was estimated at 10 cents per ton. The time the cane was in the car in all cases was about 20 hours. The difference was brought about by the delay in loading after cutting, the contractor cutting as much in one day as he could load in a week.

HAULING CANE.

To test the comparative value of oxen and mules in hauling cane from the field a record was kept of the weights of the loads.

A team of mules with a low farm wagon with broad tired iron wheels averaged with 42 loads 2,450 pounds.

A team of mules with an ordinary wagon, narrow tire, wood wheels averaged with 50 loads 2,560 pounds.

An ox team with the ordinary cart of the country averaged with 39 loads 1,580 pounds.

One team of mules hauled 55 per cent more cane per load than the oxen and the other 62 per cent more. The haul was about half mile. The mules traveled faster and averaged a little more in the number of loads per week. On the other hand the ox cart could be dumped and therefore unloaded quicker.

BURNING TRASH.

Porto Rican cane soils are deficient in humus. It is therefore advisable to work all cane trash into the ground. This is now the general practice and it should continue unless some strong reason should develop indicating a change. The only reason now apparent for burning the trash is to destroy some insect or fungus pest. Burning might help in some cases but the humus and the nitrogen would be lost. Unless for some such reason there is strong expectation of good from burning, it is best to follow the present custom of putting the trash between the rows in ratoons or plowing under before replanting.

DISEASES OF CANE.

Plants like animals become diseased more readily under unfavorable conditions. Porto Rico canes are comparatively healthy for an old cane growing country. However, there are enough of both insect and fungus diseases to cause enormous losses. Cane troubles are liable to increase rather than decrease. This will occur as long as cane is grown year after year on the same land. Again other diseases and insect pests are liable at any time to be introduced from cane-growing countries from which new cane seed are imported. It is advisable for the experiment station to import all new canes so that they may be properly disinfected before planting. It is and will continue to be the policy of this station to propagate and distribute promising cane varieties among the planters of Porto Rico without charge.

The diseases and insect pests of cane will be taken up in a later bulletin but a few suggestions at this time will prove of value. There are certain fungus diseases that are giving much trouble as the root rot and the pineapple disease. We can help greatly in lessening the losses from these maladies by planting clean seed. All cuttings used for planting should be dipped for five or ten minutes in Bordeaux mixture. While this will not kill the disease if it is in the soil, it will permit the seed to have a clean start, which is a big advantage.

Soils having a very close texture are favorable to the growth of root diseases. With healthy plants the parasites causing root rot are not very serious. It is only when under poor soil conditions the plants are weak that the damage is done.

Louisiana Station Bulletin 100 gives a description of the root disease of sugar cane caused by the fungus "Marasmius plicatus." This is apparently the same disease that we have in Porto Rico and is quite abundant. It affects the plants by destroying the roots and smothering the growing buds by matting the leaf sheaths over them. As a prevention the author recommends better cultivation, the disinfection of the seed cane, the planting of resistant varieties, the destruction of infested trash, and the rotation of cane lands.

The Hawaiian Sugar Planters' Station (a) has made a study of the diseases of the sugar cane, especially the root disease. This disease has caused the abandonment of the cultivation of Lahaina and Rose Bamboo in certain localities. The first symptoms of the disease show the plants to be apparently suffering from drought. The leaves are rolled together, turn yellow and become dry. The lower leaves mat together and white fungi can be found between them. These fungi live in the soil. The treatment recommended is the planting of resistant varieties, cultivation and liming the soil, the destruction of diseased material, and changing the soil to some other crop for a time.

In the report from Bengal, India, for 1906 (b) it is stated that certain fungus diseases, as red rot or red smut, are carried in the majority of cases by cane seed that are planted. It is recommended that sound seed be selected of resistant varieties, also the destruction of diseased material and more frequent planting.

The Queensland Agricultural Journal [1906] (c) describes a top rot of sugar cane. This disease has been known in Australia for a number of years. In some seasons nearly the whole crop has been a failure, while in others the reduction in yield has amounted to from 20 to 50 per cent.

Of our insect pests the changa or mole cricket is by far the worst. As it works under ground and at night it is hard to reach. (d) The white grub of the "caculo" also does considerable damage to cane as well as to other plants. These are found feeding opon the roots. A strong fertilizer may reach them. If this fails it may be necessary to change the field to another crop.

The sugar cane leaf hopper that does so much damage in Hawaii was introduced from Fiji. In Fiji about 85 per cent of the eggs of the insect are killed by parasites This parasite has been introduced into Hawaii where the leaf hopper is very injurious to the cane. The Director of the Sugar Planters' Station has warned us of the danger of importing this insect into Porto Rico with cane seed.

SUMMARY.

With continued favorable trade relations cane growing will increase and continue to be the leading agricultural industry of Porto Rico.

Production may be increased by improved varieties. These are being obtained by breeding at the experiment station, at some of the large estates, and by importations.

(a) Hawaiian Sugar Planters' Sta., Div. Path. and Physiol. Bul. 2.
(b) Mem, Dept, Agr, India, Bot, Ser, (1906), No. 3 p. 2.
(c) Queensland Agr, Jour, 16 (1906), No. 8, p, 498.
(d) See Porto Rico Sta, Bul, 2,

Yields may be greatly increased by better drainage, irrigation, and plowing. Liming and fertilizing can be much improved by study and experiment.

Many practices in cultivating and harvesting are capable of improvement and need detailed study.

The time has come when the diseases and insect pests of our cane fields must have the most careful consideration and treatment.

Lastly there must be stronger and closer cooperation between planters regarding the many problems relating to this most important crop of Porto Rico.

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